National Aeronautics and Space Administration

Age of the Universe:
10-25 Billion Years

COSMIC TIMES

1965

Size of the Universe:
25 Billion Light Years

MURMUR OF A BANG

Astronomers have identified a mysterious and faint cosmic radio signal from the birth of the Universe. The discovery provides the first observational evidence that the universe started with a Big Bang, and it provides clues about how it might end.

The faint radio signal comes in the form of microwaves, which lie on the electromagnetic radiation spectrum between radio waves and infrared light. The microwaves come from every direction of space, every hour of every day. The wavelength matches the radiation some scientists predicted would exist if the universe started with a hot explosion of hydrogen about seven billion years ago and steadily cooled since that time. Anything with a temperature greater than absolute zero will give off electromagnetic radiation. If the universe had originally been very hot and condensed, and then expanded and cooled, some of that radiation could still be detectable today.

This discovery of what's being called "cosmic background radiation" was made more or less by accident by Arno Penzias and Robert Wilson of Bell Telephone Laboratories. The two were trying to track down the source of unwanted microwave signals being picked up by a 20-foot horn-antenna in Holmdel, N.J. The "Holmdel horn" antenna was built to test communications with the Echo satellite that NASA put into orbit in 1960 to bounce radio signals back to Earth.

When the Holmdel horn was aimed at zenith (directly overhead) ,Penzias and Wilson found that the antenna picked up a microwave signal that matched a temperature of 6.7 degrees Kelvin. After subtracting natural microwave radiation from Earth's atmosphere and in the antenna it-

Photo courtesy of Bell Labs

Robert Wilson (left) and Arno Penzias stand in front of their horn reflector antenna in Holmdel, New Jersey. They discovered a radiation signal that matches that exptected by theorists who propose the Universe began with a hot explosion called the "big bang". This discovery was made by accident as they tried to track down the source of unwanted noise in their receiver.

self, Penzias and Wilson were still left with unexplained microwave radiation that matched a temperature of 3.5 degrees Kelvin coming from empty space. They had no explanation for it, as empty space should be absolutely cold, or zero degrees Kelvin.

Luckily, just down the road at Princeton University, some scientists had the solution. Astronomer Robert Dicke and his team were in the process of building a telescope that could detect this "cosmic back-

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ground radiation." When they heard about Penzias' and Wilson's mystery microwaves at 3.5 degrees Kelvin, they knew it was what they were looking for. After discussing the matter, the Bell Lab and Princeton teams announced the discovery in a pair of letters published in the July issue of Astrophysical Journal.

"The presence of thermal radiation remaining from the fireball is to be expected if we can trace the expansion of the universe back to a time when the temperature was of the order of [10 billion] ° K," wrote Robert Dicke and his team. This fireball was the very hot, dense ball of matter and energy that existed at the beginning of the universe.

Amazing as the discovery is, to some astronomers it wasn't really a surprise. In the late 1940s, George Gamow, Ralph Alpher and Robert Herman had said there had been a "Big Bang" and that its heat should still be detectable. In 1949 Alpher and Herman reworked some of Gamow's earlier calculations and predicted that this heat (cosmic background radiation) would now have a temperature of "a few degree Kelvin." They were correct.

However, Alpher and Herman incorrectly thought this background radiation could not be detected as it would be drowned out by starlight and other radiation from objects in space. Instead, it appears that the Big Bang has cooled in a way that channels energy into specific wavelengths of radiation. This is what Dicke and his team suspected and one reason they were planning to look for microwave radiation. It's also why they knew Penzias' and Wilson's unexplained microwave radiation was actually quite a significant discovery.

Of course, the picture is not rosy for all scientists studying the Universe. While supporting the Big Bang theory, the cosmic background radiation has caused big problems for the Steady State theory of the Universe. That theory, which recently was favored by many astronomers, says that the expansion of the universe is caused by the spontaneous creation of particles in empty space. The Steady State theory does not predict and cannot explain cosmic background radiation, so its discovery greatly weakens this theory.

Then there are the possible fates of the universe implied by the Big Bang. Either the universe will expand and cool forever as an "open universe," explain Dicke and his team, or it's a "closed universe." In a closed universe the gravity of all the matter in the universe will pull it all back together in another hot ball, breaking down matter and energy again into their basic building blocks. Then it will explode outward again in another big bang to create a totally new universe. This Dicke refers to as an "oscillating universe." Oddly, this resembles the old Steady State model in at least one way: It has no beginning or end. Sadly, however, it also offers no way of detecting what came before the last bang and no escape from being crushed together into another hot ball before the next. ♦

Big Hiss

Missed by Others

One of the biggest surprises from the recent discovery of the Big Bang's faint background radiation is how many times others have missed it.

As recently as last year Russian scientists Andrei Doroshkevic and Igor Novikov published a study on the physics of the Big Bang. They guessed correctly that if the bang happened, the remaining heat would now be between 1 and 10 degrees Kelvin. They even proposed using sky temperature measurements already made in 1961 by Edward Ohm to see if the signal could be found in them. Ironically, Ohm had gathered that same data using the Holmdel horn antenna. This is the same antenna Arno Penzias and Robert Wilson used to identify the 3.5 degrees Kelvin background radiation of the Big Bang.

Ohm had already identified in his data what seemed to be a 3.3 degrees Kelvin background radiation. He assumed it was coming from the antenna mechanism itself, not from space. Since it was Penzias and Wilson's job to subtract out the antenna's own microwave radiation, they were able to say with far more confidence that the faint excess radiation truly came from space.

There were two other near misses as well. Ten years ago Émile Le Roux reported a microwave background radiation of 3 degrees Kelvin, plus or minus 2 degrees at the Nançay Radio Observatory. In 1957 it was Tigran Shmaonov who nearly made the discovery. He reported measuring background temperature of 4 degrees Kelvin, give or take 3 degrees.

The missing piece in both Le Roux's and Shmaonov's work was they did not connect their observations to what the Big Bang theory predicted as early as 1948. They had the right data but didn't have a theory that made sense of them. It's probably safe to say that Penzias and Wilson would have had the same problem if their neighbors at Princeton University had not recognized their discovery as the background radiation predicted by the Big Bang theory. ♦

QUASARS: Express Trains to Netherworlds

Astronomers have discovered a quasar racing towards the edge of the known universe at a speed of 450 million miles per hour – that's two-thirds of the speed of light. This and other newfound quasars aren't just fast, they are really bright. The fact they are visible to us Earthlings means these strange objects must be fantastically bright. It's surprise inside of a surprise that's cloaked in mystery, since nobody really knows what quasars are.

For years radio astronomers have been spotting what they called quasi-stellar objects (quasars). Five years ago astronomers managed to match one with a visible light object seen in telescopes. But it was only two years ago that astronomers Jesse Greenstein and Maarten Schmidt managed to split the visible light of quasar 3C 273 into its spectrum of colors.

What they found in the spectrum was amazing. The lines in the spectrum which normally show the presence of certain elements, were shifted dramatically to the red side of the spectrum. This is the optical equivalent of a train whistle's tone dropping as the train moves away at high speed. In the case of 3C 273, however, the red-shift corresponded to an unheard of speed of 16 percent of the speed of light. That's more than 100 million miles-per-hour.

The same technique was used by Schmidt and Allan Sandage to find the speed of the record holder called quasar BSO-1. Sadly, neither Sandage nor anyone else can yet explain what BSO-1 is.

"We do know that [quasars] provide us with the long-sought keys to determine the size and shape of the universe," Sandage reported.

They also are confident that at least one theory is not true: Quasars are probably not coded messages from a super-civilization, as has been suggested by Russian astronomer Nikolai Kardashev. It's highly unlikely, say the U.S. astronomers, that any civilization could broadcast messages with the power of 10,000 billion suns which seems to be the power of these objects.

If there is any message from quasars, it is from the universe itself. Many astronomers hope that by seeking out and measuring the distance to more quasars using the 200-inch Mount Palomar telescope, they can see some of these objects that started shining when the universe was just seven percent of its current age. Some of that light, perhaps 15 billion years old, is only now reaching Earth. ♦

Galaxies Still Misbehaving

The latest attempts to "weigh" galaxies are still coming up a bit short. The spiral galaxy, NGC 3521 has a mass equal to the mass of 80 billion Suns. The spiral galaxy NGC 972 has a mass equal to 12 billion Suns. However, when we compare the amount of light coming from those galaxies, it doesn't match the amount of light we would expect from that much matter.. It's a puzzle.

The amount of starlight coming from the two galaxies is based on careful measurement of the galaxies' total luminosity (brightness), as recorded on photographic plates. It also takes into account the way the galaxies spread out their stars from the center out to their edges. This distribution varies from galaxy to galaxy.

The mass measurement is based on the same idea that long ago allowed astronomers to calculate the mass of the Sun. Basically, if you have a relatively small mass object orbiting a very large mass object at a known speed, you can work out the large object's mass mathematically. The same physics applies to stars orbiting a galaxy's center of gravity.

To get the speeds of stars the astronomers did not clock them with a stopwatch. Their actual motions are too small to measure with a telescope. Instead, the researchers sampled small areas of starlight from different parts of the galaxies and split the light into spectra – or their rainbows of color. These spectra contain lines that shift in proportion to the speeds the stars are moving. The speed of the stars can then be used to determine the mass of the galaxy the stars are in.

To make comparisons easier, astronomers blend the luminosity and mass measurements into a single number called a mass-to-light ratio which is based on the mass and luminosity of our Sun. Our Sun has a mass of "one solar mass" and a luminosity of "one solar luminosity", so the Sun's mass-to-light ratio is equal to one. A ratio greater than 1, implies more mass than luminosity – which means an object (a galaxy) has more mass than expected.

The NGC 3521 galaxy was studied with the 82 inch telescope at McDonald Observatory at the University of Texas. The results of the study give it a light-to-mass ratio of 4 or greater. This means this galaxy has four times more mass than its light indicates it should have. The mass of the NGC 972 galaxy is closer to what was expected, with a light-to-mass ratio of 1.2. These results were reported in recent issues of Astrophysical Journal by teams of researchers led by Margaret Burbidge at the University of California at San Diego.

These two galaxies are not unique in their "misbehavior." Other researchers are finding galaxies everywhere that have mismatched mass-to-light ratios. So far, no one has offered a clear explanation for this.

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About the only consolation these scientists may have is that their missing matter problem is far less extreme than that of astronomer Fritz Zwicky at CalTech University. In 1933 he measured the amount of light from the entire Coma cluster of galaxies. Then he measured the speeds of the galaxies as they orbited the cluster to determine their mass. Zwicky came up with a light-to-mass ratio of about 500. That means 99 percent of the matter there is hidden (not giving off light). At the moment, most astronomers seem content to ignore such extreme numbers, being, as they probably are, astronomical flukes. ♦

Supernovae Leave Behind Cosmic X-ray Generators

Two years after discovering that the Universe is awash in x-rays, astronomers are starting to pinpoint discrete sources with greater accuracy – and none of them resembles your doctor's x-ray machine.

One x-ray source is called the Crab nebula and is the remains of a star that exploded nearly 900 years ago. Those remains are often called a supernova remnant. The second source, called Ophiuchus XR-1, appears to lie in the direction of another past supernova. In fact, if you drew a map of all of the x-ray sources and compared it to a map of all of the supernova remnants, the two would look similar. Astronomers aren't sure what is causing x-ray radiation from these sources far, far away from the Sun. If Ophiuchus really does come from a supernova remnant, then astronomers can compare the two sources to peel back some of the mystique.

Photo credit: NASA

An Aerobee rocket launches from Wallops Island, Virginia. This rocket is similar to those used in recent discoveries of cosmic X-ray sources such as Scorpius X-1 and, more recently, the Crab nebula and Ophiuchus XR-1.

The task of identifying these two x-ray sources was not easy. X-rays cannot penetrate Earth's atmosphere so the trick was to get enough time in space, onboard rockets, to allow x-ray astronomical instruments to find the distant sources. Because of this property of x-rays, this new field of x-ray astronomy is rather difficult and expensive; each rocket launch only allows five minutes of time to observe. However, because Earth's atmosphere blocks x-rays, life has been protected from occasional x-ray glares found here close to the Sun.

The Crab nebula and Ophiuchus XR-1 discoveries are the culmination of about three years of rocket flights in search of x-ray sources other than our Sun. Our Sun doesn't put out a lot of x-rays, but it's the closest such source in the sky. The first rocket launch in 1962 was designed to use its five minutes in space to observe the Moon. Riccardo Giacconi and his team at the American Science and Engineering group expected to discover Moon minerals fluorescing in x-rays after being smacked and excited by heavy atomic particles (solar wind) flung out by the Sun. They were wrong.

What they found instead was far more amazing and unexpected: x-rays coming from every direction and a particularly intense x-ray source from the direction of the constellation Scorpius. They named this area Sco X-1. Unlike the Crab nebula, Sco X-1 still has not been tracked to any known object. For now, it's a space mystery.

X-ray astronomers are hoping that someday their jobs will get a little easier by placing one of their instruments in a stable orbit so they can spend more time looking at the x-ray universe. Until that day, they will be limited to observing x-rays during those five floating minutes in space with their instruments on a rocket. ♦